MECHELECIV

THE STUDENTS MAGAZINE • VOLUME 27 • MARCH 1969 • NUMBER 4

Mr. Napier

THE GEORGE WASHINGTON UNIVERSITY

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

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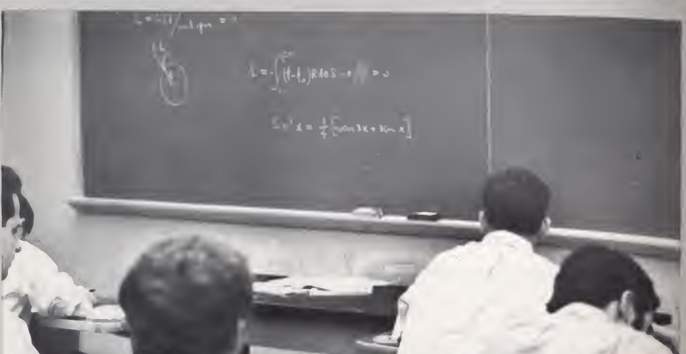
Courtesy of the National Aeronautics and Space Administration.

FRONTISPIECE

Why must professors monitor their tests?

Published at the George Washington University by direction of the Engineers' Council. Published six times during the school year in October, November, December, March, April, and May. Second class postage paid at Washington, D. C. Address communications to Mechelecív Magazine, Davis-Hodgkins House, George Washington University, Washington, D. C. 20006, or telephone 676-6726.



MECHELECIV

A serious problem in the Engineering School has finally come to light. This condition has been allowed to spread and grow until it can no longer be hidden, and serious-minded students are appalled by the extent to which it has undermined the academic strength of the school.

This problem may be delicately termed academic dishonesty, or more realistically called cheating. The faculty of the Engineering School has trusted the student body to censor itself in cases of cheating for some time, but the students have betrayed this trust, and circles of cheaters have grown in number and size.

Victims of weakness tend to band together for strength and reassurance, and for this reason individual cases of cheating in the school are rare. The cases which have been brought to light involve at least two students and usually more. The result is that these groups of students cannot hide their cheating as easily as an individual student could; consequently, their actions are more readily apparent to others.

A witness to academic dishonesty in this school has two alternatives to choose from. He may submit the students' names directly to the Dean's Council and expect to see the offenders suspended from school and punished with the grade of 'F' in the course. Or he may decide to do what most students do – namely nothing. Sometimes the excuse for apathy in this case is that the offenders are only hurting themselves, and to some extent this is true. However, most professors in the SEAS grade using a curve, and undeserved high grades in a course can hurt a conscientious student's grade. The most frequent excuse for overlooking cheating in the classroom is that students hesitate to subject their peers to the penalties which befall a person convicted of cheating by the Dean's Council. This is not considered a valid excuse by most people, but it has created a real problem since students rarely if ever turn in academic offenders under the present system, and most people will agree that any sort of honor code must be student sanctioned and enforced.

A group of students from the SEAS has offered a third alternative to the problem as presented here. The statement of their proposal is reproduced on the following page, and the question of the existence of this problem and the usefulness of the following proposal is left to the students of the George Washington University School of Engineering and Applied Science.

LETTER TO THE EDITOR

Any undergraduate engineering student suspected of academic dishonesty on a university examination will appear before a student honor council comprised of a president, vice president, and a scribe to be chosen from the student body by vote for the period of one year. This council will conduct a closed hearing to determine if an honor trial is in order.

If the honor council finds the evidence sufficient to charge the student with academic dishonesty, it will make the charge and inform the student when he will appear before the honor court in closed session. The court shall consist of the honor council presiding over a jury of five members chosen at random from the undergraduate student body of the SEAS. The student will have the opportunity to plead guilty or not guilty.

If the student pleads not guilty and is proven not guilty, the court will be charged with secrecy and the student will be released immediately. However, if the student pleads guilty, or is proven guilty by a majority of three guilty votes, then he will be informed of his punishment by the honor council.

If the student is found guilty, and it is his first conviction, he may be placed on parole by the council for a period of one year. If a student is again convicted of cheating during this probationary period, or if he has been paroled before, he may be turned over to the Dean's Council to be dealt with accordingly.

This proposal is meant to offer corrective measures for students guilty of academic dishonesty, and not as a means of circumventing present penalties.

Engineering and Science at IBM

"You're treated like a professional right from the start."

"The attitude here is, if you're good enough to be hired, you're good enough to be turned loose on a project," says Don Feistamel.

Don earned a B.S.E.E. in 1965. Today, he's an Associate Engineer in systems design and evaluation at IBM.

Most of his work consists of determining modifications needed to make complex data processing systems fit the specialized requirements of IBM customers.

Small teams

Depending on the size of the project, Don works individually or in a small team. He's now working with three other engineers on part of an air traffic control system that will process radar information by computer.

Says Don: "There are only general guidelines. The assignment is simply to come up with the optimum system."

This informal working environment is typical of engineering and science at IBM

Don sees a lot of possibilities for the future. He says, "My job requires that I keep up to date with all the latest IBM equipment and systems programs. With that broad an outlook, I can move into almost any technical area at IBM."

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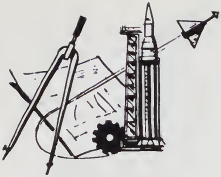

Tech News

Edited by David R. Armstrong, E.E., 70

G.E. COMPUTER USED AT CAPE KENNEDY IN LAUNCH OF HUGE SATURN V LAUNCH VEHICLE

Monitoring the preflight condition and in-flight performance of the huge Saturn V launch vehicle is only part of the assignment two General Electric 635 computer systems handle at Cape Kennedy. The General Electric 635 computer systems check 3,000 critical valves and gages of the Saturn V launch vehicle 12 times a second in the final hours before blastoff of Apollo spacecraft. In addition, these huge computers check pertinent data during flight and display in a split second the resulting data on TV-like screens.

Meanwhile, these computers perform ordinary administrative chores such as stock status and provide "instant answers" to questions on purchasing techniques. At the same time, they handle post-flight reduction data, calculations of flight trajectory, guidance paths and complex maneuvers.

Because NASA people "just can't afford to gamble" in any way with the launching of the 363-foot-high Saturn V, the most powerful launch vehicle at NASA, the checkout of the system must be continuous and fast.

During prelaunch checkout, the multiprocessing capabilities of the huge GE-635 computer come into play. In addition to the 3,000 critical checks performed 12 times a second, the computer can handle a "mission program", a very complex set of computer instructions designed to take the input for 36,000 measurements a second and translate them into meaningful terms, all in real time.

During simulated or actual countdown, the GE-635 operates around the clock. Because of the key role played by the computer during prelaunch checkout, immediate redundancy must be available to take care of any system malfunction or similar emergency.

Plans now are under way to expand the mission program to include data retrieval. Some 12 million words of storage will be available for storing and displaying the last 1,000 seconds of data, thus permitting use of "instant replay" techniques. Viewers will be given a report of what happened in the preceding 15 minutes.

The General Electric 635 computer systems check 3,000 critical valves and gages of the Saturn V launch vehicle 12 times a second in the final hours before blast-off of Apollo spacecraft.

MEYER BUILDS AESTHETIC NEW POWER LINES POLES OF INLAND INX STEEL

Revolutionary new power line structures, erected last September by the Southern California Edison Company to replace conventional towers in the city of El Segundo, were fabricated by Meyer Manufacturing, Inc. of Red Wing, Minnesota, from INX-65 high-strength steel produced by the Inland Steel Company.

Designed by Henry Dreyfuss & Associates, the aesthetic new structures replace lattice-type towers removed during a Los Angeles highway-widening project. Thirteen new towers carry a double circuit 220-kv electric power line for 1.2 miles along El Segundo's Rosecrans Avenue.

Dead-end structures feature straight 12-sided "poly-round" poles, stand 162 feet tall and weigh 55 tons. Radiant crossarm configuration on both tangent and dead-end structures increase space between conductors.

The new structures are of two types, tangent and dead-end, both featuring a modified A-frame shape with "radiant" crossarms. The radiant effect is created by angling the top and bottom arms away from the horizontal center to increase space between conductors.

The tangent structures stand up to 140 feet tall, with crossarms measuring 30 feet, 31½ feet, and 33 feet across, top to bottom. Each tangent tower features two 12-sided, elliptically shaped Meyer "Poly-12" tubular steel poles, with cross-sections positioned laterally to the direction of the power line to best carry transverse loads. The "Poly-12" poles taper from a cross-section of 30 inches by 22 inches at the base to nine inches by 6¾ inches at the top. The tangent towers weigh up to 12½ tons.

The dead-end structures, standing up to 162 feet tall, feature the same crossarm configuration but are supported by two straight, 12-sided "Poly-Round" poles – round instead of elliptical in cross-section – tapering from a diameter of 56 inches at the bottom to 13 inches at the top. Much larger than the tangent towers, the dead-end structures weigh up to 66 tons.

Both tangent and dead-end towers are equipped with high pressure water pipelines for use by maintenance personnel in washing insulators. One leg on each tower is fitted with retractable step-bolts for access to the crossarms.

In addition to aesthetic considerations, tubular steel structures offer:

- Fast, positive erection, cutting labor and equipment costs;
- Less maintenance, further reducing costs;
- Improved safety, since neither children nor small animals can ascend them; and
- An improved public image for the utility company.

POWERFUL NEW TURBOFAN PRODUCES LOWER SOUND LEVELS THAN THOSE IN USE TODAY....

One of the most powerful airplane engines ever built, the General Electric CF6 commercial turbofan, will produce lower sound levels than any of today's large commercial turbojet and turbofan aircraft engines.

The CF6 engine will power the McDonnell Douglas DC-10 trijets. Already tests have been completed with a 41 per cent scale model of the CF6 fan, mounted in a simulated DC-10 cowl. Acoustic measurements with sophisticated monitoring equipment have confirmed design predictions.

The initial tests were conducted using the unsuppressed fan configuration. Tests also were conducted using sound

A crane raises one of 13 new tubular steel power line towers designed to replace lattice-type structures (left). The tangent structure, shown in this picture, stands up to 140 feet tall, and weighs 12½ tons.

There may be a satellite in your future....

Your degree in electronics, astronautics or physics; in business, personnel or marketing; or in international affairs may have prepared you for an interesting and challenging future in the exciting new world of commercial satellite communications.

Already satellites over the Atlantic and Pacific link countries on five continents and this will become worldwide with the launching of an Indian Ocean satellite.

Live television across the oceans via satellite has added a new dimension to international understanding. People now have front row seats to history as it is being made, and they can also communicate directly with each other via telephone, telegraph, data and facsimile. This can help close the gap of misunderstanding between nations and people, and opens up new opportunities for college graduates with degrees in many different fields.

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TECH NEWS—FROM PAGE 9

suppression materials incorporated in the inner wall of the cowl to further reduce sound levels.

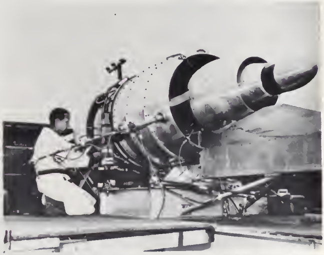
The DC-10, sometimes referred to as the "airbus", will fly at speeds of 600 miles an hour while carrying more than 250 passengers. It is considered a medium-range plane, but will be capable of transcontinental flights when needed.

The CF6 has passed all its tests to date with flying colors. It operated with 39,500 pounds of thrust less than 24 hours after it was first put on test. Eighteen hours after its initial test run it produced 45,750 pounds of thrust, although it has a guaranteed thrust level of only 40,000 pounds.

During tests to date, the big engine's specific fuel consumption rates have been below guarantees at all sea level, static, standard day-power settings. In addition, turbine inlet temperatures have been within specifications.

The new CF6 uses major core engine components of the TF39, the engine for the U.S. Air Force C-5 transport, world's largest airplane. Both the CF6 and the TF39 have higher bypass ratios than other engines being developed in the industry. It is this high bypass technology that makes possible the CF6 engine's outstanding fuel economy, 25 per cent better than today's commercial turbofan engines.

The CF6 engine for the DC-10 will be certified in mid-1970, and will enter service on the trijet with American Airlines and United Airlines in late 1971. Between them the two airlines have ordered 110 DC-10 aircraft, including options.



One of the world's most powerful engines, this General Electric CF6 commercial turbofan, will produce lower sound levels than any of today's large commercial turbojet and turbofan aircraft engines.

You ask yourself: "Was it all worth it?"

You think back over the years you've invested in that brand new degree. The hard-earned dollars you hoarded from summer jobs—the sacrifice your folks made to help see you through.

You remember the fun you had on campus—and the fun you missed, cramming for exams.

And now comes the moment of truth. *Was it all worthwhile?*

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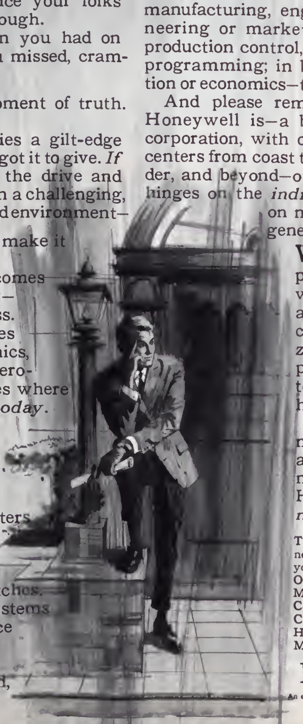

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Mech Miss

This month's Mech Miss is Corrine Goodrich, a freshman in the Columbian College. Her major is as yet undecided, and Mecheleciv suggests that she not become a librarian since her book-reaching techniques are distracting.


Decisions!
Decisions!

Industrial Archaeology For The Engineer

By Wm. S. Ellenberger

DO YOU KNOW that near Washington, D.C. is a bridge that for 40 years was the longest cut stone arch in the world? Do you know that for almost 60 years one of the principal bridges over Rock Creek connecting Washington with Georgetown was supported on water mains? Do you know that Washington's water supply was designed by an Army Captain? These and many other facts of historical and technological interest could be discovered by a student of Industrial Archaeology.

Kenneth Hudson[1] defines Industrial Archaeology as "the organized, disciplined study of the physical remains of yesterday's industries". Another source describes it as the study of "industrial monuments". An industrial monument is "any building or other fixed structure – especially of the period of the Industrial Revolution – which either alone or in association with plant or equipment, illustrates or is significantly associated with the beginnings and evolution of industrial and technical processes".

It is logical that such study should have originated in England, home of the Industrial Revolution. Serious British industrial archaeologists are engineers, architects or industrialists who specialize in the study of such fields as: coal and metals, sources of power, railways, inland waterways, roads or building materials.

While the preponderance of work in industrial archaeology has been done in England I should mention growing interest in the United States. Several studies have been carried out by the Smithsonian Museum of History and Technology[2] supplementing the National Park Service's Historic American Buildings Survey. Only recently the American Society of Civil Engineers has undertaken a program of identifying and marking engineering works of historic interest in the United States.

The December 1950 issue of Mecheleciv contains an article by Albert Moe on "Latrobe's Folly". Mr. Moe would not have called his article on the Thomas Viaduct a study in industrial archaeology; the term had not yet come into use. Nevertheless, his article contains much that would be reported by an industrial archaeologist.

The industrial archaeologist examines his subject with care, recording his findings in drawings, photographs and detailed descriptions including old documents and other relevant material. But the mere discovery and accumulation of facts is a sterile activity unless it is followed by analysis and interpretation.

Answers to the questions raised at the beginning of this article are found by the industrial archaeologist studying the Washington Aqueduct, which is the official name of the water supply for the District of Columbia. The city came into existence January 4, 1790 and for the first fifty years an ample supply of potable ground water was available from springs and wells. When the Congress was convinced that an improved public water supply was necessary for the District of Columbia it turned to the Army Corps of Engineers for technical advice. Lt. Montgomery C. Meigs, a 36 year old Engineer Officer was assigned to make the study. On November 3, 1852 he started what he later stated was the hardest three months work he had ever undertaken.[3] His report submitted February 12, 1853 gave cost and evaluation of three possible water sources. Looking ahead to the future growth of the City of Washington he recommended the Great Falls of the Potomac as a source and an eleven mile aqueduct together with reservoirs and related facilities. The cost of the recommended project would approximate $2 million and would provide 31 million gallons of water per day. The Congress accepted Lt. Meigs' recommendation and made an initial appropriation of $100,000 to start the work. He was promoted to Captain March 3, 1853. Despite the intervention of the Civil War and transfer of the work for a time to the Department of the Interior the aqueduct was put in service in 1863.

Let us now consider the Washington Aqueduct as an "industrial monument" and examine it from the standpoint of industrial archaeology. The aqueduct has undergone improvements, modifications and expansion over the years, however this article will emphasize certain work done in the Meigs period, 1853-1863. Four major components of the aqueduct will be described somewhat as they would be in an archaeological report.

CABIN JOHN BRIDGE

In the original plan the nine foot circular brick aqueduct from Great Falls was to be carried over Cabin John Creek on a bridge of tall piers and short arches similar to the Roman Aqueducts in Europe. As the plans developed, Meigs, who combined the characteristics of artist and engineer, conceived a single stone arch across the deep creek valley. When completed it was the longest cut stone masonry arch bridge in the world, a record held for forty years. It has a span of 220 feet, a rise of 57 feet and the roadway on top is 101 feet above the water. Three kinds of stone were used in the bridge: granite, gneiss and sandstone. Their se-

lection was ideal for structural purposes and the variety added to the beauty of the bridge. "The arch ring is constructed of dressed Quincy granite, 4 feet 3 inches thick at the crown and 6 feet 2 inches thick at the springing line. This arch rests on abutments of dressed Port Deposit granite. The granite arch is backed with a secondary arch or rubble arch composed of Seneca sandstone in slabs 10 inches thick, placed in a radial position to the arch. Spandrel arches are rock faced ashler with rubble backing. Foundations are of concrete and abutments and backing of blue gneiss."[4] The red Seneca sandstone gives the bridge an attractive color contrast to its surroundings. There are three other bridges in the aqueduct but none of these has the grandeur of Cabin John Bridge. Its beauty can now be seen to advantage by motorists on the connecting road from George Washington Memorial Parkway to the Capital Beltway as they approach and pass under it. Capt. Meigs did not intend that the bridge be used for highway traffic but as its use increased a parapet was added for safety which enhanced the appearance since the projecting stone courses at the roadway and the parapet give "a cornice like effect in entire harmony with the whole design."[5] Unfortunately the 20 foot roadway is a restriction to traffic on McArthur Boulevard and despite reduced speed, passing another vehicle on the bridge is not pleasant.

Some of the methods of construction used in building the bridge are of interest. Old photographs in the National Archives show the heavy timber falsework upon which the arch was built and the steam powered hoisting equipment. The Chesapeake and Ohio Canal was used for transporting construction materials. Near the bridge site a dam and lock were built across Cabin John Creek to permit boats to move up creek to the working area.

Cabin John Bridge under construction showing the false timberwork & the steam powered hoisting equipment — National Archives.

Although the name Cabin John Bridge has been in use since the bridge was completed and is now its official name Capt. Meigs, an ardent Unionist, called it Union Arch. On the east abutment appears the following inscription:

Union Arch
Chief Engineer, Capt. Montgomery
C. Meigs, U.S. Corps of Engineers
Esto Perpetua

Several other inscriptions were cut in the stone of the bridge by order of Capt. Meigs while it was being built or shortly after its completion. One on the west abutment contains the following information: "Washington Aqueduct Begun A.D. 1853. President of the U.S. Franklin Pierce, Secretary of War Jefferson Davis, Building A.D. 1861 President of the U.S. Abraham Lincoln, Secretary of War, Simon Cameron." During the period when construction was under the Department of the Interior the Secretary, Caleb B. Smith, ordered Jefferson Davis' name removed. Forty-six years later in 1908 President Theodore Roosevelt ordered its restoration.

DALECARLIA RESERVOIR

The Meigs plan of water supply envisioned an aqueduct from Great Falls and two reservoirs, one a receiving reservoir, the other a distributing reservoir. The receiving reservoir (now called Dalecarlia Reservoir) was made by damming Little Falls Branch, which also served as an auxiliary water supply. It impounded 200 million gallons of water in a 46 acre artificial lake when finished in 1858. Originally it was proposed to build a masonry dam across Little Falls Branch but this was later changed to an earthfill dam to reduce cost. An overflow spillway and a sluice tower were the other principal features of the reservoir. The sluice tower houses the sluice valves originally intended for draining the reservoir or lowering the water level for repairs. The top of the sluice tower stands like a small Greek temple[6] in a watery surrounding. The inscription on the tower tells the story succinctly: "Washington Aqueduct. Built by order of the Congress of the United States for bringing water into Washington. Begun AD1853 on the 8th day of November. Water delivered in Washington from this reservoir AD1859 on the 3rd of January. From the Potomac River AD1863 on the 5th day of December."

The original design for the aqueduct included a bypass around Dalecarlia Reservoir. It was deferred until after the water supply was placed in service and was built 1864-1867. Some improvements have been made as a result of conditions unforeseeable at the time. The principal one was the elimination of Little Falls Branch as a water source when it became polluted. A bypass drainage tunnel was

Sluice Tower at Dalecarlia as it looks today.

completed in 1895. Since that time all water used in Washington has come only from the Potomac River.

GEORGETOWN RESERVOIR

Slow sand filters for water treatment date back to 1829[7] but it was not until Kirkwood[8] designed the first acceptable American municipal sand filter for Poughkeepsie, New York (1872-1873), that filtration came into general use. Meigs considered that the state of the art at the time did not warrant filters in his water supply system. Furthermore he believed that by placing the receiving and distributing reservoirs in tandem the water would be purified by sedimentation. It was retained in the reservoirs for approximately six days before it went to the city. Heavier river mud settled to the bottom but fine matter remained in suspension giving the water a cloudy appearance. The citizens of Washington were never reconciled to using "muddy water" consequently the city wells continued to be popular for their clear water until they became contaminated and were closed. Filtered water has been supplied to the city since 1905.

A screen chamber and valve vault at the lower end of Georgetown (distributing) Reservoir originally controlled the flow of water into the distribution mains. Here, as elsewhere, Capt. Meigs left his name figuratively and actually on his work. The stairs to the valve vault bear his name boldly – M. C. MEIGS – in the cast iron stair risers.

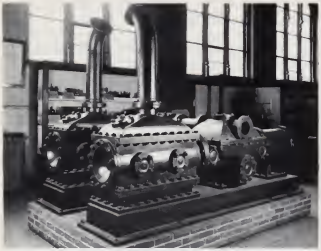
ROCK CREEK BRIDGE

Of all the structures in the Washington Aqueduct Capt. Meigs was most proud of Cabin John Bridge (already described) and Rock Creek Bridge. The latter was unique in that two 46 inch diameter cast iron pipe arch ribs were to act both as a water conduit and to support a 26 foot roadway. The arch is quite flat, 20 feet rise from the springing line and 200 feet span between sandstone abutments. It is described in considerable detail in a contemporary newspaper report which says in part: "This bridge is particularly remarkable for the double duty which the arch performs. While it supports a roadway, forming a beautiful and much needed communication, by which the traffic between the cities of Washington and Georgetown is carried over, the water of the Washington Aqueduct is conveyed into the city of Washington through the pipes of which the arch is composed. To guard against all danger of freezing, the pipes are lined with staves and resinous pine timber, three inches in thickness, leaving a clear waterway in each rib of three and a half feet in diameter."[9] After almost 60 years of continuous service the bridge was replaced in 1916 taking the live and dead load of the bridge off the two water pipes. They are now barely visible from the underside of the new bridge.

An even more noteworthy feature of this bridge was a water power driven pumping engine located in a chamber in the west abutment. It raised 10,000 gallons of water per hour 204 feet to a reservoir a mile away on the heights of Georgetown supplying residents who could not otherwise be served. This reservoir was at the southeast corner of Wisconsin Avenue and R Street on the site now occupied by the Georgetown Branch Library. The pumping engine was designed and built by Henry R. Worthington under his patent of 1855. It was the first pump used for the distribution of water in the District of Columbia and is believed to be the first machine of its type used in this country. Fortunately it has been preserved in the Smithsonian Institution although it is not currently on display. The designer and builder of the pumping engine will be recalled as one of our early mechanical engineers, founder in 1845 of the pump and machinery manufacturing business that still bears his name and as one of the founders of the American Society of Mechanical Engineers in 1880.

ANALYSIS AND INTERPRETATION

The foregoing descriptions and comments are part of what an industrial archaeologist would develop in a study of the Washington Aqueduct. Earlier in this article I said that the mere discovery and accumulation of facts is a sterile activity unless it is followed by analysis and interpretation. What can we conclude from the study of this indus-



The water power driven pumping engine which was used for the Georgetown Reservoir – The Smithsonian Institution.

trial monument? I find two significant conclusions. One relates to the man; the other to his work in the engineering environment of his time. They are closely interrelated.

First consider the man. Engineering has evolved from art to science and technology. In the past there has been a close relationship between art, architecture and engineering. Michelangelo was a sculptor and architect; Leonardo da Vinci was an artist and engineer. Early in the 19th century architects performed the functions of architect, engineer and constructor. It was during construction of the Washington Aqueduct that architecture and engineering were identified as separate professional disciplines. The American Society of Civil Engineers was founded in 1852; the American Institute of Architects was founded in 1857. Cabin John Bridge and Rock Creek Bridge both reveal Capt. Meigs' architectural and engineering abilities. Despite the problems of transportation and communication he exercised close control over large increments of design and construction. The Congress was so impressed with his ability that appropriations contained restrictive wording such as that found in the fiscal year 1861 appropriation: "For the completion of the Washington Aqueduct, five hundred thousand dollars, to be expended according to the plans and estimates of Captain Meigs and under his superintendence." (Underlining added.) His managerial skill carried the aqueduct to completion despite interrupted appropriations, political intrigue and the Civil War. We conclude that he was a man of strong will and keen mind with a family tradition of stubborn self-reliance and implicit devotion to duty.[10]

Some of his designs may be criticized, notably the use of cast iron as a structural material. Engineering design at mid 19th century was based largely upon empiricism tempered by one's own experience. As to his general plan for the aqueduct, we must applaud his foresight in recommending a proposal that met the raw water requirements of the city for 63 years and is still in constant use. It was not the cheapest of the three alternatives considered but it paid off in the long run.

Now consider the work in the engineering environment of the time. The construction employed materials and methods proven by experience. Exceptions were the long span over Cabin John Creek, cast iron arches over Rock Creek and the innovation of a water power pumping engine to raise water to the heights above Georgetown. Economical expenditure of appropriated funds dictated foregoing certain desirable refinements. For example tunnels were left rough at the overbreak. Years later they were finished and lined. The specifications for materials and workmanship were typical of the period but grossly inadequate as to technical definition by todays standards. On major projects steam hoisting engines were used but most of the work was hand labor. Inspection methods were personal judgment of the construction inspectors, however construction photographs show cast iron water pipe being subjected to hydrostatic acceptance test. The specifications for the Worthington pumping engine are the epitome of brevity – less than half a page.[11]

Proof of the adequacy of construction lies in the Washington Aqueduct Annual Report for 1909 which says in part: "As a general rule the conduit after 46 years of service is in excellent condition and the brick lining is almost invariably strong and sound." Had the Rock Creek Bridge been built earlier it would have received greater acclaim since it is believed to have been the longest cast iron arch in the world, but by the time it was completed (1862) cast iron was discredited as a structural material.

Capt. Meigs was not the most brilliant technical engineer of his time but he certainly was an engineer of great ability carrying out important public works. After a lifetime of work, most of which was done in and about Washington, D.C. he could have said (quoting Christopher Wren's epitaph) "If you seek his monument, look around."

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[8] Merdinger, Charles J., Capt. (CEC) USN, Civil Engineering Through the Ages, Reprinted from The Military Engineer.

[9] Quoted from a news clipping dated 1860 in Capt. Meigs' Scrap Book.

[10] See Weigley cited above.

[11] The specifications consist of four brief sentences. The contract price of the machine installed in the bridge abutment chamber was $4,000.

The author, William J. Ellenberger, received his Bachelor of Science in Electrical Engineering and a Bachelor of Science in Mechanical Engineering from George Washington in 1930 and 1934 respectively. Since then, he has been an active member of the alumni: Vice-President, Engineer Alumni Association; member of the Governing Board, General Alumni Association. Mr. Ellenberger served in the Army during World War Two and the Korean War; he is presently a retired Colonel, his decorations including the Order of the British Empire and the Army Commendation Medal. Presently serving as an Engineer Consultant to the Department of the Army, Mr. Ellenberger worked in the Office of the Chief of Research and Development of the Army for fourteen years. He has contributed to the preparation of technical publications, the discussion of professional papers, and has written articles for "The Gear" of Theta Tau. He is a charter member of the Gamma Beta Chapter of Theta Tau.

THE SPECIFIC question put to me is this: Why should an engineering student devote part of his curriculum to the study of the social sciences and the humanities?

One answer is simple: There is no more reason for an engineering student to do so than for any other student. Nor is there any less reason.

Speaking largely, the terms "social sciences" and "humanities" denote (somewhat ambiguously) major areas of human nature and the human condition. Not everyone has to become an engineer, nor an artist, nor a philosopher; but all human beings must involve themselves within the total dimension of their humanness. If they do not, they grow up as partial cripples, well developed and strong in certain areas of their total capability as a human being, atrophied in others. In short, they become a "mere" specialist. Any contrivance that devotes its total attention to the performance of a specialized, mechanical, technological task without regard for humane and social values is called a machine – or, if it bears a human shape, a slave. Any man may become machine or slave simply by developing only one of his capabilities. It is the purpose of social and humanistic studies (and other areas of the liberal arts) to remind every specialist of his inescapable commitment to the total range of human values and capacities – aesthetic, emotional, spiritual, moral, intellectual.

The Engineering Student And The Liberal Arts

By Dr. Calvin D. Linton

The development and enrichment of these capabilities depend on study. No one is born with a fully developed sense of the beautiful, for example, any more than one is born knowing calculus. Muscles grow with use. So do the invisible fibers of the brain. The engineer who knows only his own subject knows very little of that – to paraphrase Mill. The same is true of any specialist; for the fullness of life, like the fullness of a symphony orchestra, is the result of the harmonious working together of myriad notes. A specialty (whether it be medieval grammar, engineering, or topology) is a fine instrument – as good, say, as a piccolo. But one does not want to limit his orchestration of life to an incessant solo on one instrument.

The measure of a man's success as a human being is the range of his informed interests. When we were children our range was very small, and this was no discredit to us. We have known admirable six-year-olds whose total range of interests embraces no more than model airplanes, television, and peanut butter. As one grows older, however, he gets interested in more things, chiefly the influence of education. At the college level the need for broadening becomes urgent, for one then enters adulthood and his perimeters tend to grow rigid. The major purpose of a liberal education is to achieve this broadening before rigidity sets in.

Now I know that "liberal education" is a tired phrase, but the reality the phrase points to is alive, vigorous, and of increasing importance in a world where the crippling of over-specialization has reached epidemic proportions. If we could convincingly define the term "liberal arts", there would be no difficulty in demonstrating the need for all educated people, including engineers, to study them. Let us try.

An essential step in making any definition is to identify purpose. Fortunately this step is fairly easy in the case of the liberal arts, for we can say confidently that the purpose of a liberal education is *to transmit civilization from one generation to the next*. Other activities of man also serve this function, but no other human enterprise has this purpose as its central, exclusive objective.

And yet this vital force in our society – a force which is among the first to be counteracted and exterminated in any totalitarian society – is widely misunderstood, so widely misunderstood that I was asked to write this article on why

an engineer should seek a liberal education. Jacques Barzun has sadly declared that "The liberal arts tradition is dead or dying." (This is another way of saying that civilization is dead or dying.) And the cause? "Both teachers and students," continues Mr. Barzun, "are responding to the spirit of the times. They are impatient with everything that is not directed to the development of talent into competence." In other words, they are impatient with any education not directly productive of the marketable skill of the specialist. Such an emphasis on mere performance of a mechanical task, as we have already noted, perilously approaches the creation by our professional schools of machines or slaves instead of free men.

Now, machines and specialists contribute immensely to the comfort and physical well-being of our age, but it may safely be said that they do not transmit civilization, for civilization is not the product of skills or machines. Great civilizations have occasionally in the past coincided with great technological advances, but it is dangerously misleading to equate the two manifestations. Civilization *uses* machines and skills, but it *reproduces* itself in the living continuity of the liberal arts.

What, then, are the liberal arts, and how are they the channels through which civilization is transmitted from generation to generation?

Our understanding of the phrase is impeded by the modern connotation of both words of it. "Arts" here does not mean, as we feel the word always should, simply such areas as painting, music, sculpture, and the like. The English word comes, via Greek, from the Latin word *ars,* meaning ability or power to perform. It is related to the words *arm, armament, army, armor* – that which performs a defined purpose.

Hence there is no reason why the word "arts" in the phrase "liberal arts" should not apply just as much to such areas of man's ability and competence as physics, mathematics, and chemistry as it does to literature, music, and philosophy.

The second word of the phrase, "liberal," is even more slippery, for it has become entwined in the folds of that vast serpentine monster called politics. No two persons define "a liberal" in precisely the same way, though everyone is aware that the word suggests freedom.

Again, it is the Latin word which gives us our central meaning. *Liberalis* in the phrase "liberal arts" means those skills and studies suitable to *free men.* It is not the "arts" that are free, or that bestow freedom, for only that which possesses self-consciousness and free will can be free. Rather, the liberal arts are those disciplines, intellectual activities, skills, capacities, powers appropriate to free men as distinct from slaves.

To the ancient world the free man was, of course, a legally definable person; but more importantly he was a man intellectually and spiritually released from those confinements, limitations, chains that inhibit the slave from becoming fully himself. The free man had time to devote to his own enrichment and broadening, the slave did not. Today we tend to think of leisure as a time of mental and physical relaxation, but we may more creatively view the leisure of a free man, spared the grinding pressure of devoting every waking hour to making a living, as the time when one exercises the entire range of his capabilities outside of his professional specialty. (Thomas Jefferson, retired at Monticello, was not idle. Architecture, music, agriculture, science, religion – the whole range of the liberal arts – filled his every moment.)

We have said that the liberal arts are those means by which civilization is passed from one generation to the next.

But perhaps this is begging the question. What do we mean by "civilization?" In important measure it is the task of the liberal arts to find out, to determine what are those good things which men should do all the days of their life on earth. I obviously do not pretend to possess the wisdom necessary to define completely so vast a term as "civilization".

But some truth we *do* know about it. We know that it is a *condition of mind, not an inventory of possessions nor an array of machines and instruments.* We know that no one is born civilized. We know that any civilization can end in an instant, after millenia of painful growth – just as an individual, after years of self-development, can die in the wink of an eye, and no one can inherit his abilities and powers.

Civilization is another name for enlightened freedom. It is not generically related to technology, machines, medical progress, or the like – although if none of these commodities are present, civilization is hampered. The biological genes cannot carry culture. The child, as J.B. Priestly has said, is born a perfect barbarian; and, despite all the nice theories of optimistic romantics like Rousseau, his totally unguided natural development will be exclusively biological and instinctual. Furthermore, he may, on the basis of technological training alone, become a highly skilled machine and perfect barbarian at the same time. To many, this assertion is both wrongheaded and offensive, for it suggests that civilization is not definitively evidenced by the visible things in which we take such pride – airplanes, super-highways, freezers, X-ray machines, bridges, space-probing missiles, and such like. Surely, many feel, the evidence of our high level of civilization and culture is in these things. It is corrective to such naivete, however, to remember that Nazi Germany was the richest nation in the world in all such things at the very moment it almost succeeded in grinding the civilization of Europe to dust. The barbarism of Germany and the culture of the free world were not distinguishable because of the difference between a Messerschmidt and a Spitfire, but in the difference between the mind of Hitler and the mind of Churchill.

Civilization is a state of mind, and the liberal arts are dedicated to fostering that state. It is a condition as fragile, and as eternal, as a thought. It can be the possession only of free men. Among the first steps of any modern totalitarianism, as we have earlier noted, is to eliminate from its higher educational systems all dimensions of a liberal education, and to substitute that kind of education appropriate only to slaves – how-to-do-it education, explaining man as instrument. In 1952 Albert Einstein warned of purely technological education precisely in these terms, saying that it would produce "a kind of useful machine, but not a harmoniously developed personality. It is essential that he acquire . . . a vivid sense of the beautiful and the normally good. Otherwise he . . . resembles a well trained dog." Einstein himself was a good example of the liberally educated man, as at home in philosophy, aesthetics, history, music, and other things as he was in theoretical physics.

It is sometimes said that the liberal arts are "irrelevant" because they concern the past, and we are of the present. "We *know* more than the ancients did," some say. And T.S. Eliot answers: "Precisely; and they are that which know." Furthermore, it is not the nature of ideas to age or wither. Machines wear out, run down, are replaced by improved models. Such ideas as freedom, purpose, duty, beauty, love are eternal – but they live only as they are alive in people's minds. It is the work of the liberal arts to make sure that the ancient gold is constantly reissued in current coinage.

By this time, my reader (if I still have one) may feel that I have gone a long way from my specific topic: why include courses in the social sciences and the humanities in an engineering curriculum? What has all this high-flown talk about freedom and civilization to do with the requirement that I take History 39-40, or English 51-52, or Economics 1-2? Will these courses instantly and fully provide the student with the great dimensions we have been speaking of, and will they relate themselves to the needs of our time for purpose, value, meaning, unity?

The honest answer is, not nearly so well as they should. The virus of specialization, of the slave mentality, has infected every discipline of our institutions of higher education. The futile idea that a whole man is not possible, but a whole society is – the organic view of society as more vital than any individual within it – has pulled down the blinds on many a long vista. To revert to our metaphor of the orchestra, our universities all too often consist of a score or two practice rooms (departments) where skill on a single instrument is acquired; but the orchestration (not to mention the conductor) is lacking. Liberal arts faculties *should* be unified, dedicated to common values, aware that each discipline can make only a partial contribution to the whole vision, but it lets no cat out of the bag to say that liberal arts faculties here and elsewhere are *not* so unified.

But that's all right. Civilization is not institutionalized. A liberal education is not the exclusive prerogative of establishments of higher education. The important thing is that such institutions still offer richer and more varied resources for the individual *seeking* a liberal education than any other social instrument in the world. A liberal education cannot be given, but it can be got, and if one does not want it, he does not deserve it. After all, the world was not created with fully staffed liberal arts colleges tastefully distributed about the garden. Man made them because he needed them. He can remake them, if necessary, if he still believes in his own greatness, dignity, and invidual wholeness. If he thinks of himself as only a cog in the machinery of society, only a specialized worker in the ant heap, he needs no liberal education, only a professional one.

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SCIENTIFIC MANAGEMENT, OPERATIONS RESEARCH, and SYSTEMS ENGINEERING

By Dr. H. E. Smith, Chairman at the Department of Engineering Administration

IT MAY SEEM STRANGE to relate these fields in an article's title, but there are interrelationships which will be pointed out. Also distinctions can and will be made.

F.W. Taylor, early in this century, enunciated his approach to management termed "scientific management." He made a significant contribution to industry and management in that he brought about an emphasis on the analysis of operations as opposed merely to observations of performance. This emphasis on careful, measured analysis may seem obvious or even trivial today, but the ramifications of systematic, quantitative measurement and analysis brought about profound changes in management and labor relations. Taylor was a mechanical engineer who studied operations and elements of jobs to determine how such units of work were performed and how they could be improved by new or altered methods established after analysis and measurement. Taylor was prone to insist on perfection in performance after analysis revealed unit times and improved methods of doing work. This attitude, in its time, proved troublesome and Taylor was the object of much criticism. In the long view of history this reaction was really unimportant. What was important was the fact that measurement and analysis led to better decisions than those made before this time. Such decisions may not have led to the optimum or best situation, as Taylor insisted (the one "best way"), but certainly the way was shown for making better decisions. Taylor even utilized the "team" idea (an earmark of the operations research approach) as shown in his and his twelve associates' work in metal working. Taylor was followed by Henry Gantt who is perhaps best remembered for the GANTT chart, a device for monitoring or measuring progress of work or operations, and by Frank and Lillian Gilbreth who contributed to the field of scientific management by their micromotion studies. These few references do not make for a complete exposure of those who contributed to the development of scientific management. They suffice only to emphasize the change in outlook – the careful, precise "scientific" measurement of operations of interest to management – rather than evaluating only the end results. Taylor's work was carried out primarily at the shop level. It did not take long for such an approach to be extended to other levels of operations. Of course, with the advent of operations research or operational analysis as the British called it, the systematic analysis of the broad field of operations in general developed. Thus, "scientific management" in its careful systematic analysis of how operations were or could be performed for promoting greater efficiency, productivity, and improvement belongs in the trilogy with operations research and systems engineering as the title suggests.

Operations research, as a discipline, had its origins just before World War II. Like many other developments it did not come about full grown. There were antecedents, which will be mentioned here only briefly. Thomas Edison and his studies in antisubmarine warfare was one. In England, Professor Blackett and his "circus" (a mixed team approach and characterized as a "circus" by the British) in their work in operational research in radar beginning in 1939 are probably pioneers in OR. There is now no sure way of pinpointing how "operational research" crossed from England to the United States, but research into operations certainly began in this country after December 7, 1941. The emphasis here strangely enough was on radar problems for the United States Army Air Force. Dr. Philip Morse of MIT, recognized as a pioneer in OR in this country formed a research team to analyze results of sea and air attacks

against submarines and to study ways of improving the effectiveness of U.S. forces against enemy submarines. This work is undoubtedly a forerunner of the Operations Evaluation Group (OEG) which devoted considerable attention, as its name suggests, to operational analysis of military activity. Dr. Ellis A. Johnson formed a group at the Naval Ordnance Laboratory to study mine warefare operations. Another example of the early work are the studies on bombing accuracy for the USAAF conducted by Dr. William J. Yonden (a member of the SEAS faculty in 1965) and others.

After WWII the National Security Act of October 1947 emphasized the evaluation of weapons and weapons systems. The Weapons System Evaluation Group (WSEG) was established with Dr. Philip Morse as its technical director. The Operations Research Office (ORO) was established at Johns Hopkins University to carry out studies for the U.S. Army. The hallmark of OR had been the predictive value of guiding the choice of alternatives on a theoretical basis, primarily in the military sphere.

The extension of analytical studies applied to military problems and other problems in the non-military sphere was a natural development because the skills used in wartime activities as aids to decision making had been so successful. Improvements in efficiency and profitability were logical areas for the use of operations analysis. The early work of industrial engineers as consultants to management and the effectiveness of OR added a new dimension, viz, the "whole area" was considered amenable to analysis. Complexity, now subject to analytical and mathematical treatment, could become manageable. This dimension brought new interest in OR because of the results achieved out of the abilities and mathematical competence of experienced analysts. The National Research Council established a committee in 1949 to stimulate interest in OR, and published the report "Operations Research with Special Reference to Non-Military Applications" in 1951. In early 1951, a small group of experienced analysts met to discuss formation of a society, and in midyear the Operations Research Society of America (ORSA) was born with Dr. Morse as its first president.

Having emphasized the part played by Dr. Morse in the development of OR, it will be of interest to the reader to read his definition:

> *Operations research is a scientific method of providing executive departments with a quantitative basis for decisions regarding operations under their control.... It is an organized activity with a more or less definite methodology of attacking new problems and finding definite solutions... But the term 'scientific method' implies more than a sporadic application and occasional use of a certain methodology; it implies recognized and organized activity amenable to application to a variety of problems and capable of being taught.*

This definition, it will be noted, emphasized not only analysis but research into the nature of problems.

The phases of operations research activity in analysis of a problem are:

Formulation of the Problem
Construction of a Mathematical Model
Derivation of a solution from the Model
Test of the Model and the solution derived from it
Establishing controls over the solution
Implementation – Putting the Solution to Work

One of the critical phases, if not the most important, is the description and construction of a model representing the problem, the situation, or the operation under study. The solution proposed, based on the model, establishes alternatives $a_i - a_n$. Of these solutions, one is to be adopted. It is the general purpose of OR to make a selection from these alternative courses of action, $a_i - a_n$. Each action a_j is analyzed and the consequences of following each course are established. The consequences are determined and expressed in such terms as dollars earned, targets hit, etc. or stated in more general terms in quantitative measures, so that comparisons may be made to indicate the merits of the alternatives. The operations research "customer" selects one action and the consequences of such an action that he wants. The solution selected optimizes what the problem solver (or his client) seeks. Thus, losses following one course of action may be minimized; the profit resulting from another course of action may be maximized. It may merely be a problem of how best to make cuts from a material produced in a certain size (metal sheet, for example) in order to utilize most of the material, viz, minimize scrap. Optimization is the ideal that the OR analyst seeks, just as Taylor sought perfection or more practically stated, the "one best way." Yet, this discussion no matter how brief cannot fail to acknowledge that such a statement is incomplete. It is incomplete because not *all* alternatives can be considered in some situations, not all exogenous events can be taken into account. There is no hope for making exclusive and total assumptions about *all* events having possible influence on a problem and its solution and therefore subjecting events to total control. Therefore, the OR analyst must use judgment, skill, and caution to select those partial optimizations which are adjudged fruitful, and to select those criteria for evaluation by which alternatives are judged. Although simply stated, there is a maxim in OR represented by the expression $E = f(x_i, y_j)$ which says that

CONTINUED ON PAGE 30

the measure of effectiveness of solutions is a function of the controllable vs. the uncontrollable variables. The effectiveness measure is used to judge the merits of alternatives.

The techniques or the body of knowledge available for analysis are many and multifaceted. It is not possible here to present detail, but effort will be made to provide basic descriptions. Linear programming is the one approach most closely associated with management science. It has wide application but relationships must be linear for application. It is a technique for selection of an optimum combination of factors from a series of interrelated alternatives, each subject to some limitations. Examples of what this statement means may be seen in the scheduling of production lines to meet demands or goals such as: blending of amounts of materials at minimum cost; allocation of limited funds (or resources) to elements of an organization for best results. Linear programming can be used, therefore, to divide a number of limited resources among a set of conflicting demands. Demands for resources obviously are related since if one demand is satisfied in some way, the second cannot be satisfied in the same way because of the limitations. Management may want to minimize loss, maximize profit, minimize stock level, etc., creating the principal requirement in application of linear programming. This function would, of course, involve various proportions of variables (e.g. resources used) corresponding to quantity(s) sent by particular transportation routes or modes, and other variables. The values of these variables will be controlled by other limitations (amount of time available during which certain machines may be used, tonnage of raw material available, number of men available, etc.). Use of the technique finds that optimum combination of products and quantities and the other factors would yield the overall profit for the company. While this description implies a production operation, it must not be understood that applications of linear programming are restricted to production problems.

Non-linear programming treats relationships which are non-linear; dynamic programming is based on the mathematical notion of recursion and is designed, for example, to optimize policy type decisions. Dynamic programming divides the problem under study into stages, thus it is also called a multi-stage decision process. What does this mean? Assume a situation exists in which a sequence of choices has to be made, each choice being two or more possibilities. There is one type of possibility when once a choice is made the outcome is uniquely determined (deterministic); the other type occurs when the outcome is drawn from a set of possible outcomes according to some given probability distribution. Bellman, who devised the technique, enunciated his now famous principle of optimality, viz, in the multistage process, with a given state associated with a stage, an optimal policy for the remaining stages is independent of the policy arrived at or used in the previous stages.

The early work in Queuing Theory was done by Erland, a Danish telephone engineer who was studying fluctuating demand for telephone facilities and the resultant effect on automatic dialing. The reader, of course, has had personal experience with queues or waiting lines, but the applications of queuing theory in which we are interested exist in the economic, military, and social sphere – e.g. landing of aircraft; loading and unloading ships in a port facility; timing of traffic lights; radio communications; production flow, etc. The aircraft units arriving to land, the ships arriving to dock, etc. arrive either regularly or irregularly as to time at a point called the "service center" (airport, dock terminal). This center has channels or stations to accommodate the units arriving, but these must wait until the station or channel is free, and this may be after a regular or irregular working time. The units entering (arriving) at such a station may be separated by equal time intervals; they may be separated by unequal but known time intervals; they may be separated by unequal time intervals whose probabilities are known (random intervals). The times required to service may be constant, variable but known, or random. For a waiting line to occur, all that is needed is for entries or service times to form irregular intervals. There are many situations in industry in which the cost of time lost by personnel in waiting lines and the cost of additional facilities can be determined accurately. Queuing theory application can give solutions which provide lowest total cost of the lost time or persons in the waiting line for service and the cost of labor or facilities or both to provide service.

Game Theory is an important but not widely used OR technique. We have all played games; however, for our purposes here we refer to game theoretic problems in which conflict situations exist over time. Game theory does not cover all possible diversity in situations of conflict. It is doubtful that any mathematical technique could. Imagine an individual in a situation out of which several possible outcomes can/will result and such an individual has personal preferences regarding outcomes possible. He may have control over some of the variables but not full control. There may be several individuals having preferences desiring the outcomes preferential to them. These individuals may not agree on what preference should prevail, and we have a conflict. Any one individual's desire for the preferred outcome is a problem of maximizing "expected utility." Consider n players in a "game". These players all choose well defined outcomes (based on preferences). They do this without the knowledge of how others chose (applications to military strategy become apparent). These outcomes are those which each player appraises in accordance with his own tastes and preferences. The problem, to which game

theory addresses itself, is what choice should the player make in order that his "partial" preference over the outcome benefits him most. Von Newmann developed the famous "minimax principle" to guide such decisions.

These few paragraphs do not exhaust the knowledge or methodology that OR can bring to bear on operational problems. It is important, however, to reiterate one point. In management, the aim to be sought is optimal use of resources. This is the aim of operations research in assisting management. It does so because of the fact that OR contributes to precision in analysis and evaluation of the factors bearing on problems. It is an applied field. In situations of complexity it substitutes purely analytical "devices" through iterative, heuristic, and simulative approaches.

In the space available, it is not possible to provide an exhaustive differentiation between operations research and systems engineering, or for that matter systems analysis. It is commonly asserted (although not universally accepted) that OR is concerned with existing operations. The object is to optimize the use of resources in these operations, make better or best use of resources by precise allocation, etc. Systems engineering in its classical manifestation emphasizes the planning and design of new systems or the replacement of existing systems or redesign of existing systems. Systems engineering was formally recognized first and evolved in R and D organization. The first formal effort at teaching systems engineering is believed to have been in 1950 at MIT.

Both Operations Research and Systems Engineering have developed over the years; OR out of science, SE out of engineering. The SE problem is one of a large system requirement, consisting of control, computer, and communication parts functioning in a highly integrated and interdependent manner to achieve an overall performance, reliability, schedule, cost, maintainability, power consumption, weight, and life expectancy. It is a multi-loop, multi-loop problem. Accordingly the aim is to arrange the system, the decisions, and the parameters so that interactions are made most favorable for realization of the system objective.

The concept of wholeness is vital in systems engineering. A weapons system, for example, may be a myriad of components, but it is not a collection of fragments. In the study of systems as a whole we must use a strategy which at every step is designed in terms of fitting the parts together correctly at the end of the analysis/design.

The great complexity of systems has led to standard approaches. The most basic outlook is the operating maxim that extremely complex processes may be more easily dissected into a large number of simple units than a small number of complex units.

Complex historical processes in which all variables change with time (evolve) can be dealt with most straightforwardly in terms of recurrence formulae that express state at time $t + 1$ as a function of the state of the system at time t. Thus, we can try to understand the process not in its entire history (life span) but rather in terms of cause and effect relationships operating through the time interval. The recurrence relationship is common throughout mathematics. Matrices of transitional probabilities are stochastic versions of a recurrence relationship. Difference equations, dynamic programming, and "loops" in computer programming are all related to recurrence relationships in which the output from one stage is input to the following stage.

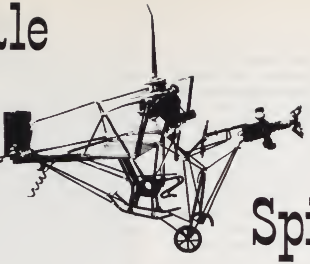
Systems engineering methodology recognizes that each system is an integrated whole even though composed of diverse specialized structures and subfunctions. It further recognizes that any system has a number of objectives, and that the balance between them may vary widely from system to system. The methods seek to optimize the overall systems functions according to the weighted objectives, and to achieve the maximum compatibility of its parts. Some systems emphasize performance and relegate cost to a lesser level objective. Others are cost sensitive and are made less responsive to reliability.

Systems engineering is related, of course, to engineering design. There are those who believe that it will become recognized as part of the general design process, if not the heart of it. Going further, there are many who believe that the aggregation (in the sense of coalescence) of engineering design, operations research, systems engineering, cybernetics, and other fields will evolve as systems science.

The contribution of these areas of knowledge to our society needs no elaboration. While it is certainly not easy to depict the shape of the future in our fast developing society, Professors Bell and Brzezinski of Columbia have outlined major aspects. Bell believes decision making in large organization will become more formalized, the systems approach being emphasized, and will require more knowledge of quantitative methods. Brzezinski sees a "technetronic" society with an extension of scientific methods of decision making. These few ideas do not, of course, complete the vision of these men, but since both believe that scientific decision-making will be extended, as do many others, they are a fitting note on which to conclude a discussion of decision making and aids to the process.

* * * * * * *

Tale Spin



Did you hear about the basketball game between the CE's and the gta's? The CE's quit at half-time and two hours later the GTA's scored their first goal.

* * * *

EE: Do you know why they don't allow GTA's to swim in Lake Michigan?

CE: Because they leave a ring around the shore!

* * * *

Campus cop: Why are you walking nude through the campus?

GTA: I was at a party in Arlington when suddenly the lights went off. Then a voice said everybody take off your clothes and go to town — looks like I'm the first one here!

* * * *

CE: How long is a hair on a rabbit?

EE: Two seconds.

ME: What's the punch line?

* * * *

CE: How did Captain Hook die?

EE: He wiped with the wrong hand.

* * * *

EE: I have a sure cure for hangovers.

CE: Oh, what?

EE: Don't stop drinking.

Coed: Oh, here's the place Mother told me to stay away from. I thought we'd never find it.

* * * *

He: What are you doing with that letter on your sweater? Don't you know you're not supposed to wear that unless you made the team?

She: Well?

* * * *

Old timer: Son, do you have a fairy godmother?

Little boy: No, but I have an uncle we're a little suspicious of.

* * * *

"I think I've finally cured my husband of coming home in the wee hours of the morning," the wife proudly announced.

"Last night when I heard him fumbling downstairs I yelled:

"Is that you Harold?"

"How did you cure him?" questioned her friend.

"His name is John."

* * * *

Two young girls were returning home from church one night when they were accosted by a pair of hoodlums in a dimly lit alley. "Dear Lord," prayed one girl, "Forgive them, for they know not what they do."

"Shush," whispered the other, "this one does."

The Air Force doesn't want to waste your Bachelor of Science Degree any more than you do.

B. Sc. Those letters have an impressive sound.

But they won't be so impressive if you get shunted off into some obscure corner of industry after you leave college. A forgotten man.

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Suppose, for example, you wanted to become a pilot and serve as aircraft commander on airplane crews. You'd plan missions and insure that the aircraft is pre-flighted, inspected, loaded and equipped for the assigned mission. You'll be trained to fly exciting aircraft.

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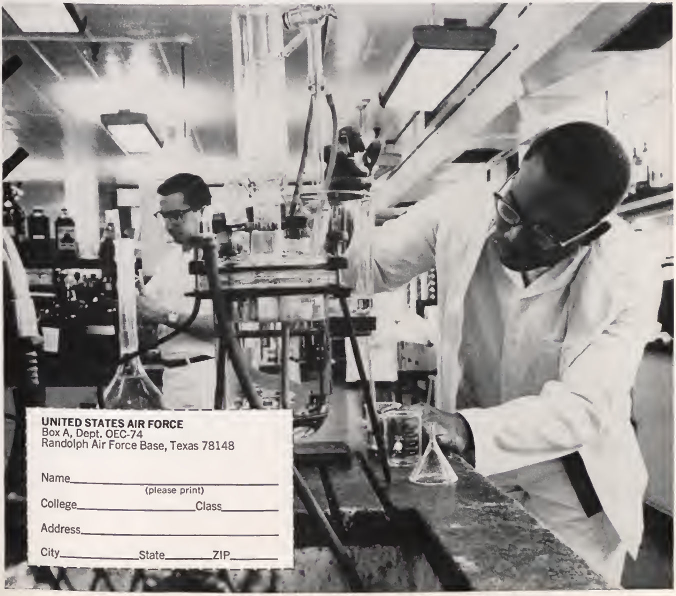
Wouldn't it be pretty nice to enjoy officers' pay and privileges? And serve your country, as well? Also, you get retirement benefits, 30 days' paid vacation, medical and dental care.

B. Sc. Very impressive letters.

Now, *do* something with them.



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